UNBALANCE IN THE BIOLOGICAL PROCESSES OF THE ECOSYSTEM OF THE SEA

A noticeable and in some cases even a significant modification of the species composition took place during the last decade due to the invasion of the introducers and other anthropogenic reasons caused the destruction in the functioning of the marine ecosystems. The destruction manifested itself in the

- impoverishment of the species diversity of the sea fauna;
- changes of the size-age structure of the population;
- destruction of the food connections and increase of natural mortality;
- bioenergetics unbalance;
- destruction of the interconnection host-parasite;
- eutrophication of the estuaries and the shelves shallow-water areas;
- increase of the abundance of the pelagic crawfishes;
- decrease of natural reproduction of the aboriginal biota

All these ecological transformations and deformations separately came to get noticed as early as the 1950–70s and were analyzed more systematically in the 1980s in the papers of MMBI (Matishov et al. 1986; Matishov and Pavlova 1990). Thus, for instance, in all the investigated seas as the result of the degradation of the populations and the habitats of fishes, birds, seals, whales the forage productivity of the ecosystems lowered, but this provided the necessary level of the energetic balance of marine and coastal (on the mainland coasts and archipelagos) animals due to the calory content. This way of development predetermined the deficiency of forage for the marine fauna with quite different food preferences (phytophages, fish grazers, birds grazers etc.).

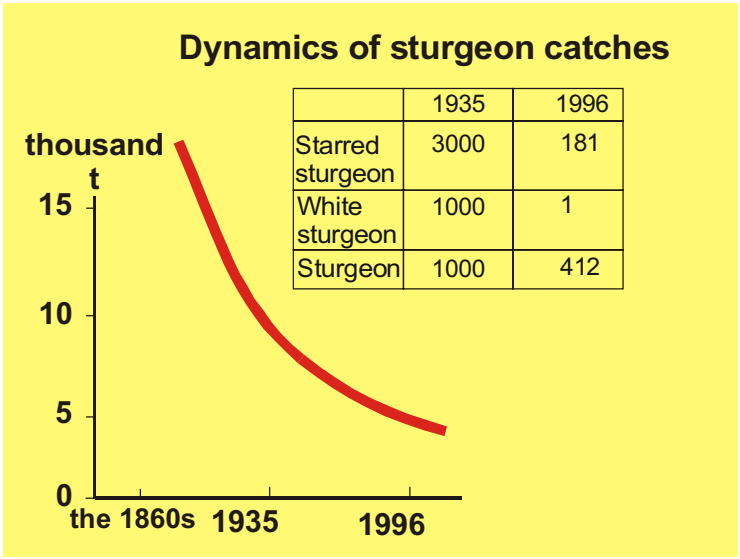
IMPOVERISHMENT OF THE SPECIES DIVERSITY OF THE SEA FAUNA

The dynamics common to all marine ecosystems leads to the situation that alongside the whales, seals, birds many valuable fish species happen to be under the threat of extinction. This is especially typical of the Caspian Sea.

During the last decade, the species diversity progressively decreased (**Fig.** 58). In the Azov Sea 23 of 62 fish species which occurred earlier are not detected anymore (Tsunikova 1997). The above mentioned process finds its manifestation in the fact that only the Azov Sea – the Don River zarthe population preserves its commercial importance out of the 3 populations of zarthe inhabiting the Azov-Black seas basin. In the Dnieper River commercial catches of this fish during last 5 years are not observed. The Kuban River population of zarthe is also on the verge of extinction (Belousov 1998).

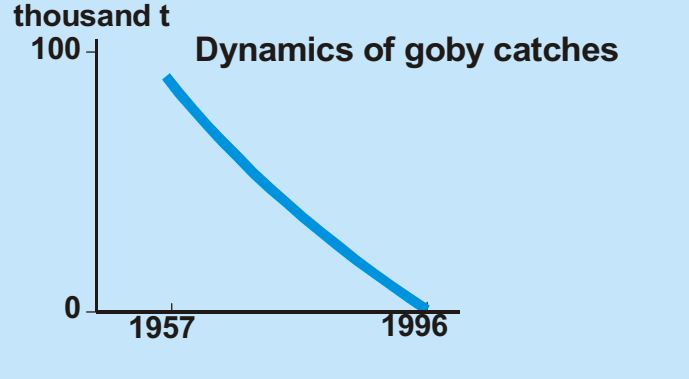
Endangered valuable fish species

The Caspian Sea (Pavlov 1994)
Caspian lamprey *Caspiomyzon wagnery*
Spiny sturgeon *Acipenser nudiventris*
Caspian salmon *Salmo trutta caspius*
Sheefish *Stenodus leucichthys*
Caspian shemaya *Chalcalburnus calcoides calcoides*



	1935	1996
Starred sturgeon	3000	181
White sturgeon	1000	1
Sturgeon	1000	412

Species	State of the populations	
	1860s	1980-90s
Sturgeon	All the species are relatively scarce in catches and their ratio is determined by the abundance of the population	Low abundance (supported only by the artifical restoration)
Starred sturgeon		Low abundance
White sturgeon		Occurs very seldom
Sterlyad		In missing
Ship		In missing In the 1980-90s the ban of sturgeon fishery at seas is introduced



Fish species	Food objects
Sturgeon	Molluscs, polychaeta, goby, anchovy
Starred sturgeon	Goby, mollusks, polychaeta
White sturgeon	Goby, mollusks, anchovy, bottom invertebrates
Sterlyad	Larvae, anchovy, sprat, mollusks
Ship	Goby, anchovy, mollusks, sprat

Fig. 58. Decrease in the number of species of the sturgeon in the Azov Sea

Zanthe *Vimba vimba perca*
Caspian barbel *Barbus brachycephalus caspicus*
Tera barbel *B. ciscaucasicus*
Bulat-mai barbel *B. capito*
Sea zander *Stizostedion marina*
The Sea of Azov (Volovik et al. 1996)
Starred sturgeon *Acipenser stellatus*
Great (white) sturgeon *Huso huso*
European carp *Cyprinus carpio*
European eels *Silurus glanis*
Gobies *Neogobis sp.*
Kerch shad *Alosa pontica*
Black Sea shad *Alosa maeotica*
Black Sea turbot *Psetta maeotica*
European (mud) flounder *Platichthys luscus*
Volga shad *Alosa kessleri volgensis*

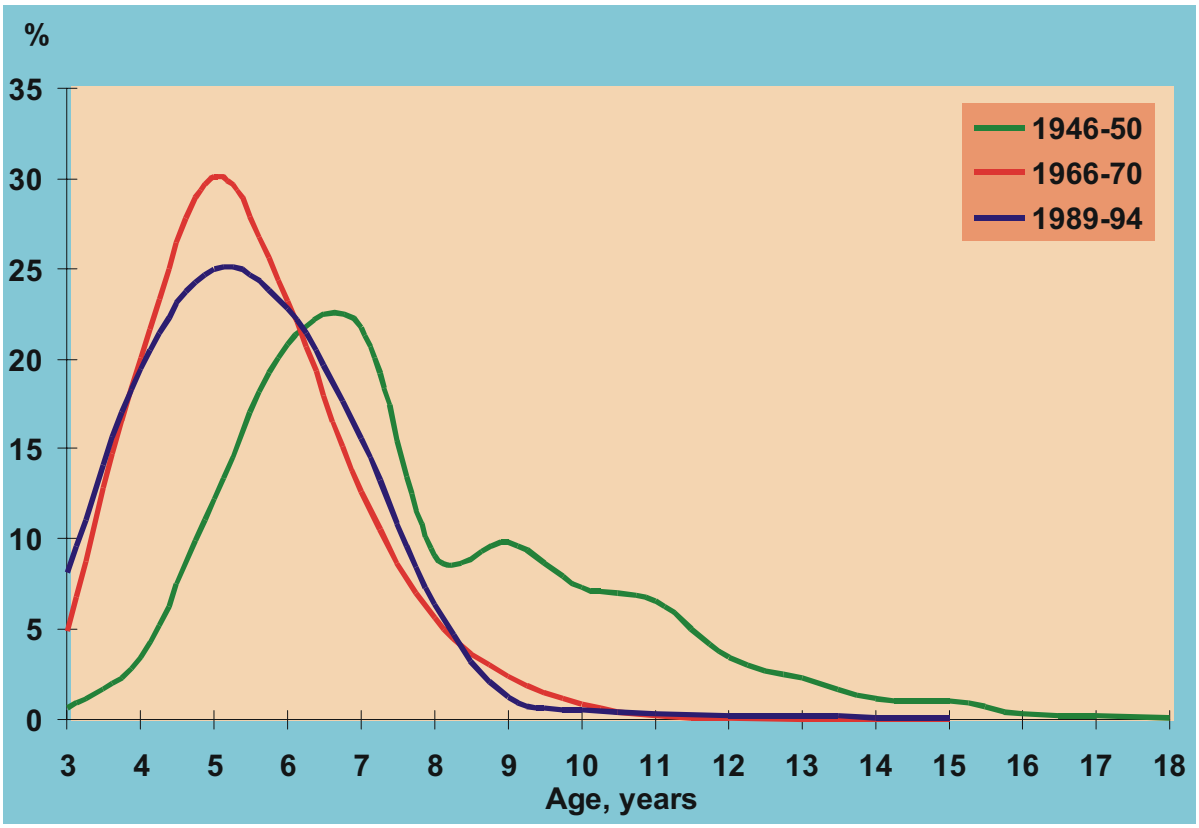
The increase of salinity in the Azov Sea promoted development of high concentrations of the coelenterates: in 1975 the jelly fishes *Aurelia aurita* and *Rhizostoma pulmo* occurred in large amounts, since 1989 expansion of the comb jelly *Mnemiopsis leidyi* began, other jelly fish species were superseded by the comb jelly, which, obviously, was intensely feeding on zooplankton. Zooplankton species composition was reduced (17 species in 1991 out of 41 in 1971), its absolute abundance decreased from 53.9 to 12.3 thousand specimens/m^3, and biomass – from 2.1 to 0.63 g/m^3 (Partaly 1997).

CHANGES OF THE SIZE-AGE STRUCTURE OF POPULATION

Anthropogenic impact on the marine ecosystems caused not only the fall of the total biomass but influences noticeably the sex and the age structure of the populations of the commercial fish species. (**Fig.** 59). Analysis of the age structure of the cod population in the catches made in 1946–1979 shows that with the increase of the intensification of trawl fishery the fishes of the elder age groups (15–20 years old) practically disappeared in the catches by 1970, by 1980 the 10–15 years old cod was practically absent in the catches At the moment the bulk of the catches is composed of 3–6 years old fish (Borisov 1978, Ponomarenko 1996).

The bulk of the Atlantic cod becomes mature (length is about 90 cm) by the age of 8–10 years. Cod spawns every year, sometimes up to 6–7 times during its life. In natural conditions the maturation growth rate of cod fluctuates depending on the climate, productivity and other factors. If in the 1930–50s more than half of the Lofoten-Barents Sea cod became mature at the age of 10–11 year old, in the 1970s it matured at the age of 8–9 year. (Ponomarenko 1996).

In the Azov Sea, as it is noted in the recent papers of *YugNIRO* (Korkosh and Pronenko 1998), long term changes of the salinity regime and the accumulation of the pollutants on the bottom sediments of the shelf «deforofmed» the species composition of the benthos, which is the main food item for the sturgeons. As the result the growth rates lowered and the length-weight indices decreased. This conclusion is made on the basis of the comparative analysis of the marginal rays of pectoral fins saw preparations for the Azov Sea sturgeons for the years 1922–1924 and 1995.



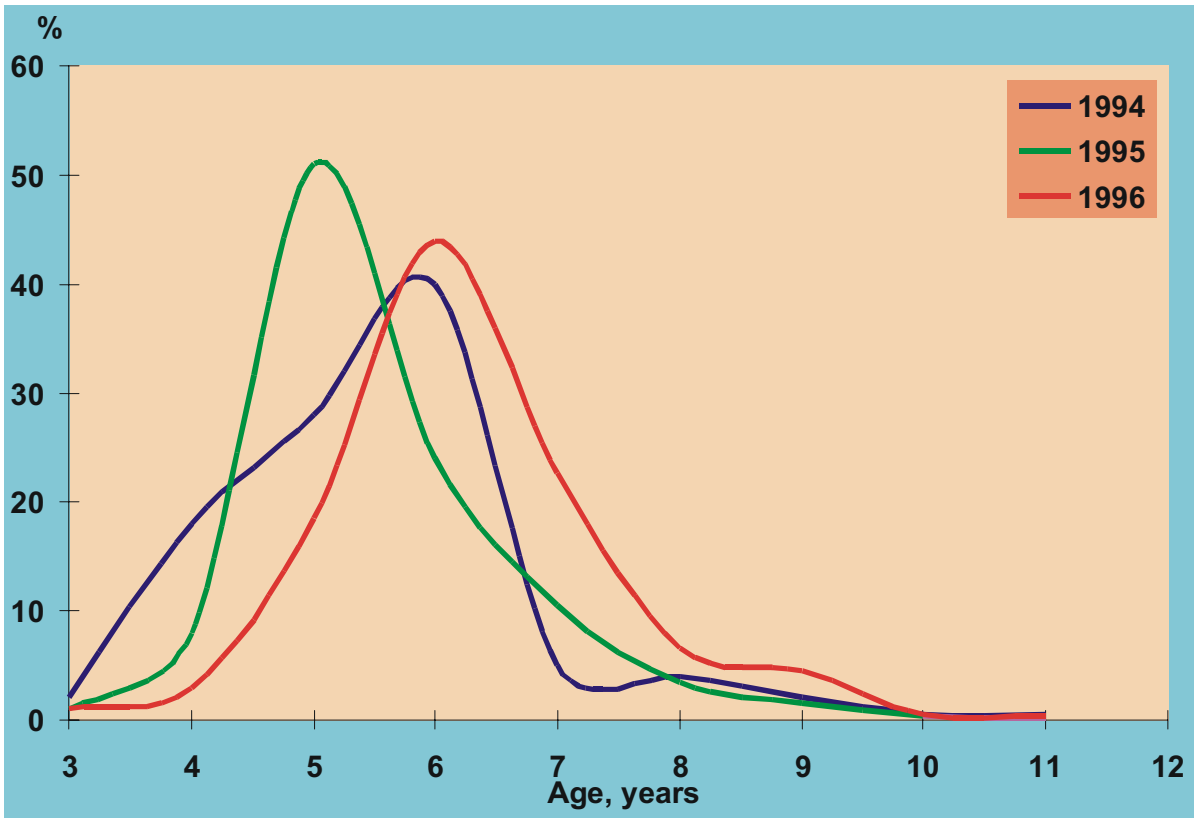


Fig. 59. Age composition of the Arctic-Norwegian cod during different periods and years

BREAKAGE OF THE TROPHIC LINKS AND INCREASE OF NATURAL MORTALITY

Numerous phenomena, for instance, lowering of the predation pressure, mass development of the planktonic crawfishes in the pelagic zone, radical shortening of the abundance of the main commercial fish species, the introduction of the food competitors caused significant disproportion in the ecological pyramid (**Fig.** 60). All this led to the growing unbalance of the food chains and to the extreme form of the trophic interrelations-the excessive cannibalism.

For instance, the forage spectrum of the Barents Sea cod includes 200 species of organisms and 20 among them are of primary importance. Being omnivorous, cod prefers capelin, herring, polar cod, the young haddock. Current deficiency of capelin in the diet of cod led quite naturally to the eating out of the young cod (Karamushko and Karamushko 1995). In addition, eating out of the young cod by other predators – long rough dab, spiny skate, harp seal, minke whale – increased in 1992–1998 (**Fig.** 61).

In many mass Barents Sea birds species the increased cannibalism and a sharp lowering of the recruitment of the abundance is also observed (Krasnov et al. 1995). This phenomenon was a consequence of deficiency of forage of fish. (Fig. 62, 63). It is known that every sea gull female, as well as other bird species female, needs 200–400g of small fish daily during feeding period.

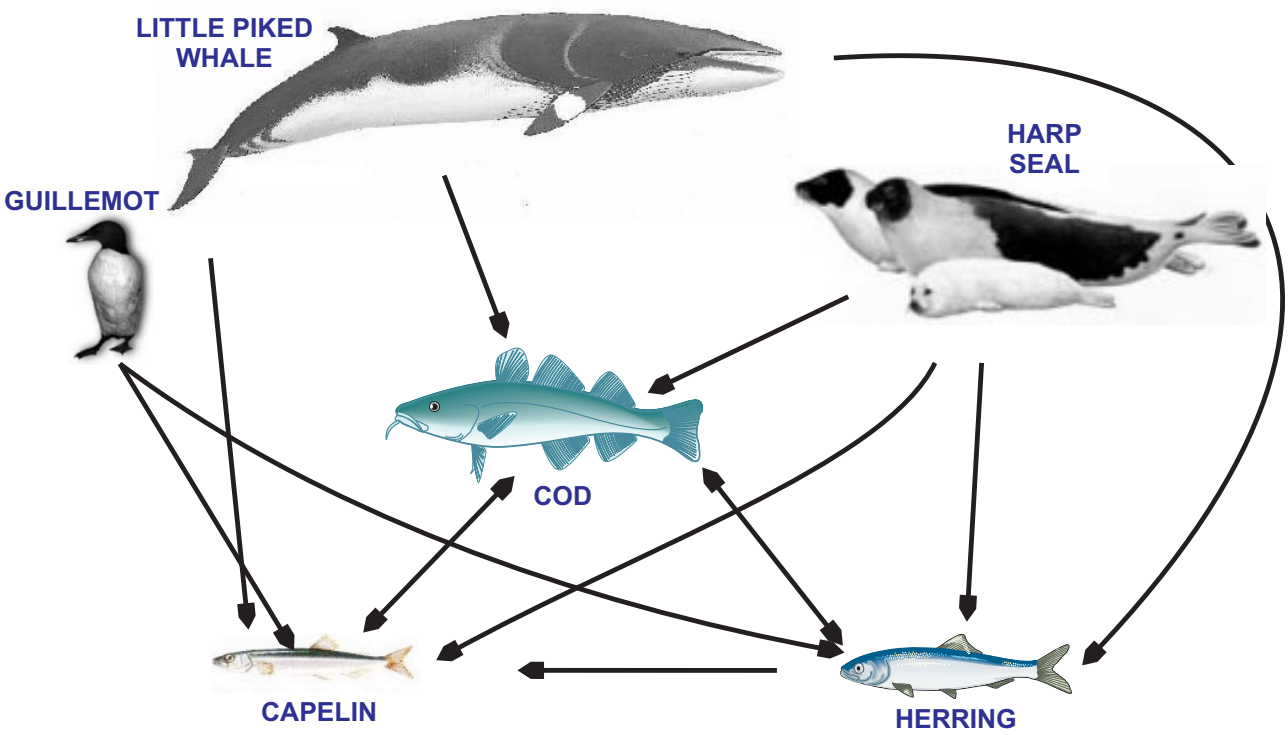


Fig. 60. Inter-specific interrelations in the Barents Sea ecosystem

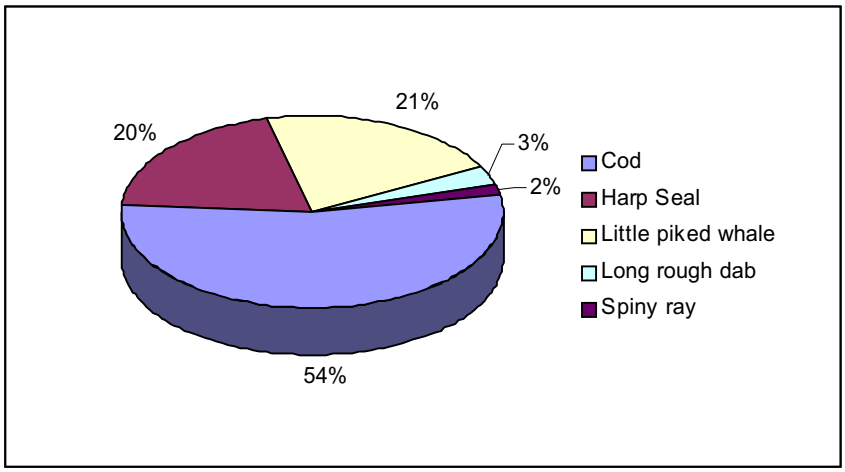


Fig. 61. Ratio of young cod consumption by different predators in 1994-1996 (by PINRO data)

In the southern seas the expansion of different exotics significantly disrupted the natural food chains. The food deficiency during the common kilka and anchovy (sprat species) feeding migrations influenced negatively the fatness, size-weight composition and other qualitative indices of the fishes. Decrease of the common kilka and anchovy abundance in connection with the competition of the comb jelly resulted in the increase of natural mortality of their main predator – zander. As the result, the multigenerational structure (up to 15 generations) the Azov Sea zander population was destroyed (Kukarina 1995).

I - Ainovy Islands
II - Seven Islands Archipelago

Index	Puffin		Herring gull		Great black-backed gull	
	I	II	I	II	I	II
Herring	25.4	16.0	32.7	14.3	40.6	23.7
Capelin	12.7	17.0	3.8	10.2	—	9.8
Sand eel	5.4	46.0	—	—	3.1	4.6
Cod	—	2.0	5.8	18.6	31.2	30.9
Number of stomachs examined	55	100	52	322	32	194

Seven Islands archipelago

Index	Thick-billed murre	Atlantic murre	Razorbill	Puffin	Black guillemot
Herring	27.0	24.0	37.7	16.0	12.5
Capelin	12.6	18.7	21.7	17.0	7.2
Sand eel	16.2	19.7	33.3	46.0	17.0
Cod	14.4	22.1	11.6	2.0	25.0
Goby	—	—	—	—	5.7
Gunnel	—	—	—	—	10.2
Number of stomachs	111	208	69	100	— 88

Fig. 62. Absolute occurrence (%) of the mass fish species in the forage of the colonial birds on the Ainovy Islands and on the Seven Islands archipelago (by Belopolsky 1971)

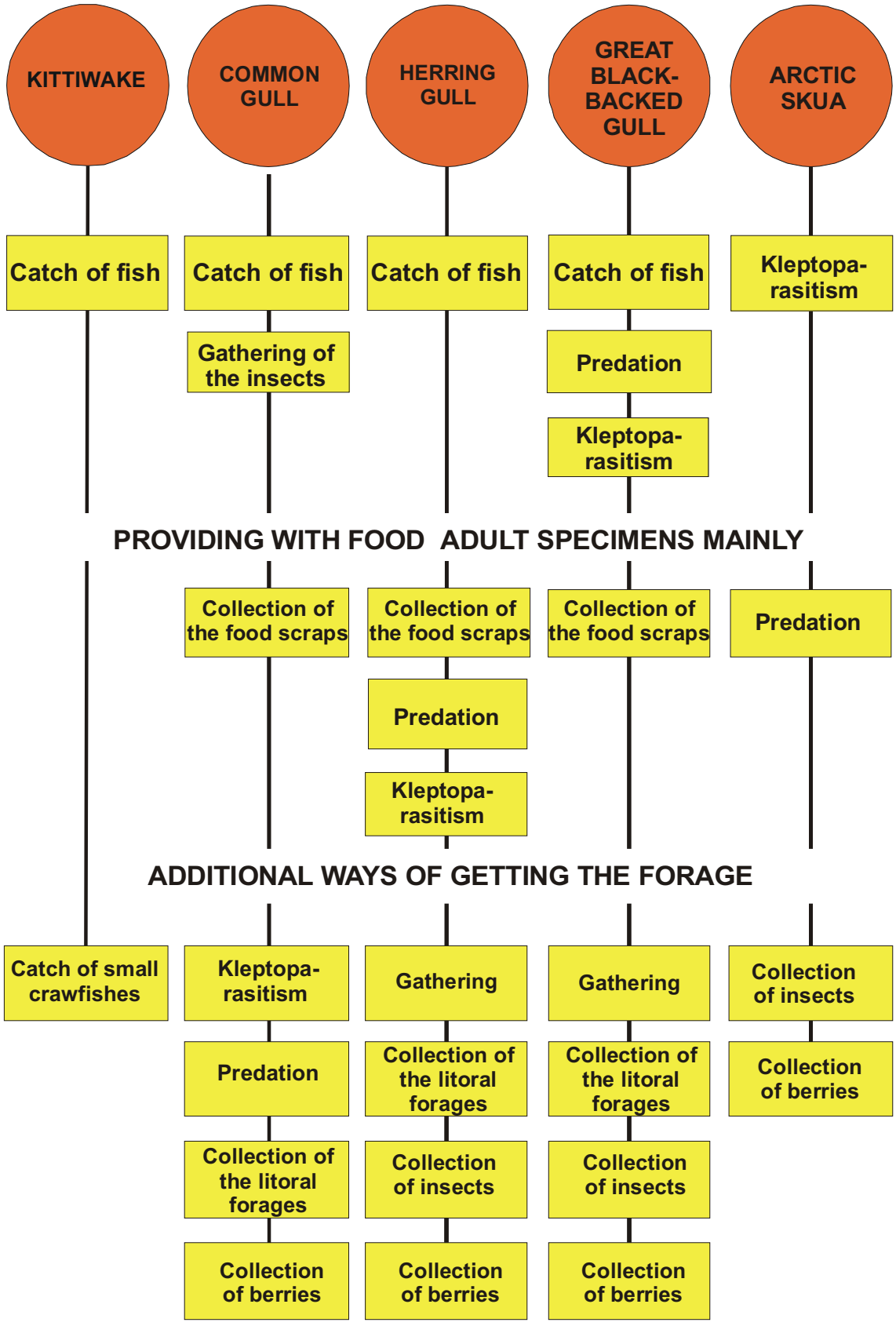


Fig. 63. Ways of obtaining forage by the sea gulls in the conditions of the Seven Islands archipelago in 1978-1987 (by Krasnov et al. 1995)

BIOENERGETIC UNBALANCE

Distortion of the population structure in the marine communities causes shifts in the character of biochemical processes in the ecosystems. The biogene elements inflow into the sea in the areas of colonial birds species nesting, mass spawning of both bottom and pelagic fish species, feeding migrations of small whales, lay out and reproduction of seals decreases. The natural way and the productivity value of all the links of the food chain in the marine ecosystem becomes broken (Fig. 64, 66).

The question is about a complete disappearance of the feedback process . For instance recently capelin when the biomass of the mature part of its population was 3–4 mln ton delivered into the water during spawning about 55,200 t (dry mass) of the organic matter (Timofeev 1988). 10 fold capelin population decrease and, consequently, reduction of its reproductive product and seminal fluid production, might cause significant disturbances in the natural cycles of the planktonic communities productivity.

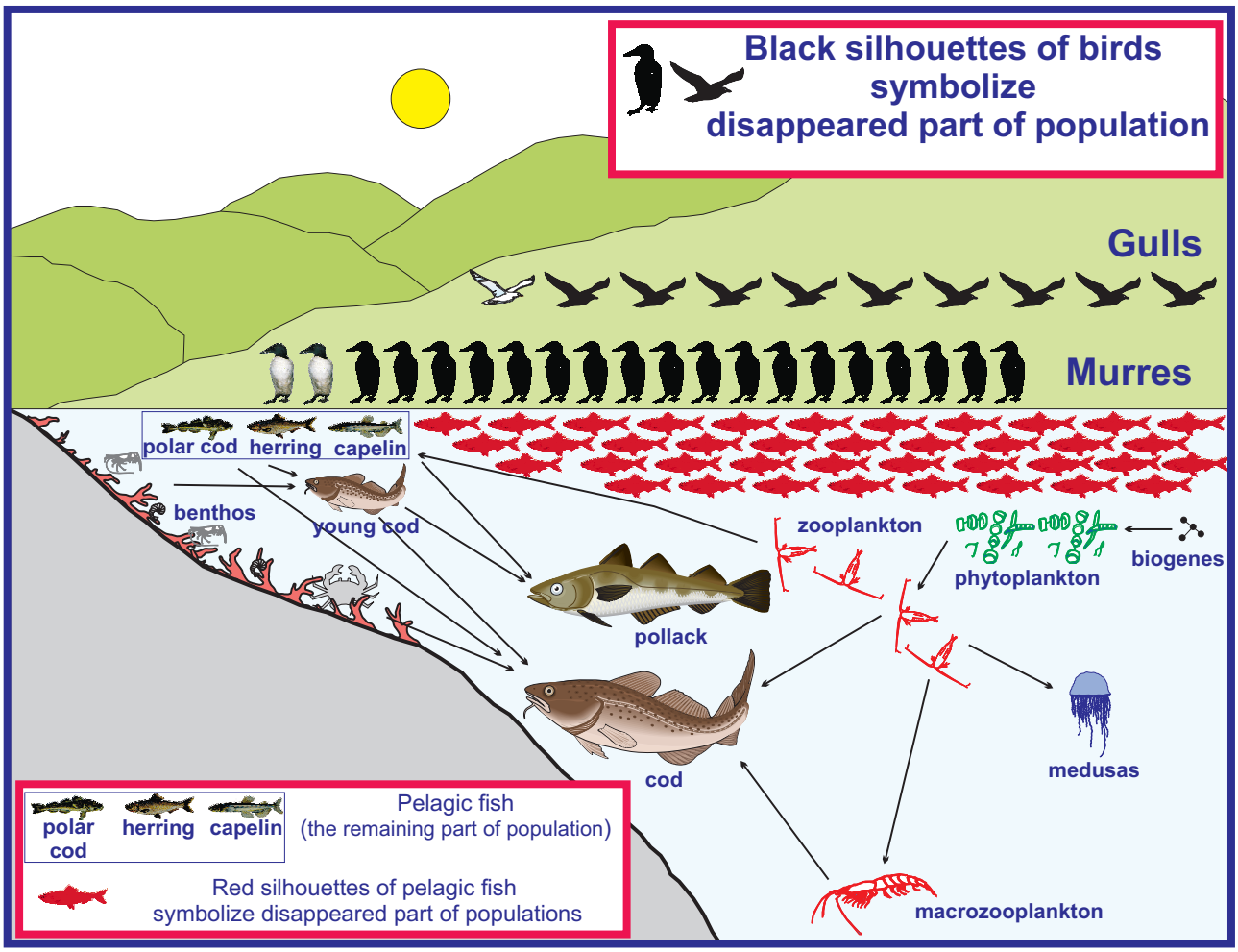


Fig.64. Scheme of bird colonies degradation in connection with the disruption of food interrelations

BREAKAGE OF THE HOST-PARASITE INTERRELATIONS

Regulatory function of the parasite fauna in the biological processes is well-known (**Fig.** 65). For the Barents Sea ecosystem the breakage of the connection parasite-host as the result of an almost complete catch out of the polar cod may serve a typical example . This mass fish species the catches of which in 1971 reached 330,000 t served as the main link of the energy transfer in the animals world within the vast areas around the Novaya Zemlya, the Vaigach Island, the Franz Josef Land – that is on the area on the boundary between the Kara and the Barents Seas. This ecological place of polar cod is clearly seen on the example of its parasite fauna which served as the main catalyst for the helminthes (35 species) circulation. Polar cod was the key element of the trophoparasite chain of the Arctic basin biota (Karasev 1988).

As it is known in the Azov Sea in the 1960–70s, 30% of zander at the age of 3 years was affected by the parasite (ligula of the *Blockh* genus) (Troitsky 1973). As a result of the sharp decrease of the young zander reserves, which is the main food item of the ihchthyophagous populations of waterfowl (the main host of the parasites), not only disrupted the normal reproduction of the European cormorant and other birds species, but quite probably led to the destruction of the natural host-parasite interrelations. And this, in its turn, may cause serious consequences for the whole Azov Sea ecosystem.

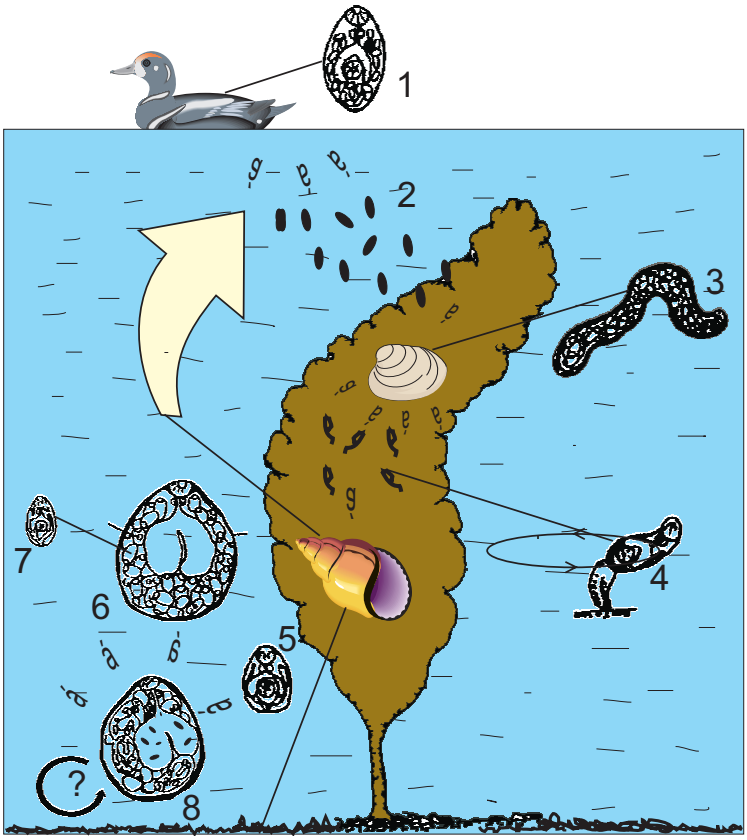


Fig.65. Parvatrema sp. life cycle (by Galaktionov 1996)
a) marita in the stomach of the common eider; b) the egg with miracidium; c) the daughter sporocyst in the bivalve mollusk Turtonya minyta (the first intermediate host); d) cercarea; e),g) the stages of development in the prosobranch mollusk; f) the young metacercarea of the first parthenogenetic generation; g) metacercarea of the second parthenogenetic generation containing the invasion for the final metacercareas host

EUTROPHICATION OF ESTUARIES AND SHELF SHALLOWS

A sharp increase in the 1970–90s of the municipal and industrial sewerage with a high concentration of biogene elements and a wash out of the fertilizers from the agricultural fields became the reason of the unprecedented sharp outbursts of the microalgae development and an extremely high level of primary production. Eutrophication manifests itself in the development of the oxygen deficiency in the water layers near bottom, in the «water blossom» due to the intensive development of phytoplankton during the vegetation peak and in the species diversity lowering. These phenomena are especially typical of the shallow-water areas of the southern seas. They lead to the mass die off due to oxygen deficiency and a sharp decrease of the abundance of both commercial species and their food items.

In the Azov Sea a constant increase of the amount of the organic compounds which strengthened especially after the regulation of the river run-off caused mass deaths almost every year. For the period 1960–1980, the area with hydrogen sulphide contamination of the near bottom layers was in average of the order of 99,000 km^2, or 60–70% of sea (Bronfman et al. 1979; Bronfman and Khlebnikov 1985). As the result of the hydrogen sulphide impact, bottom and near bottom fauna died, including fishes (the gobies, mainly). Already the first storm mixed the water and eliminated the mortality phenomenon, however the restoration of the perished fauna takes more time.

INCREASE OF THE QUANTITY OF PELAGIC CRUSTACEANS

Abnormal increase of the pelagic crawfishes at the predation pressure loosening became typical for the primary links of the marine ecosystem. On some sites their biomass reaches 50–80 kg/m^3. After the destruction of whales in the marine waters of the Antarctic, krill biomass reached an enormous value of about 600 mln t. This is much more than the total weight of all people inhabiting the Earth. At the moment due to the similar reasons the Barents Sea crawfishes (calanus, euphausiids, amphipods -hyperiids) are not utilized (Fomin 1995). The value of under-exploited food might reach probably 50–60 mln t.

In the Black Sea simultaneously with the growth of biomass and the changes of the phytoplankton structure similar phenomena take place in the zooplankton populations. Its total biomass in the north- west part of the Black Sea became 10 times as much in the period from 1960 till 1981. And the specific weight of the *Nocticula* increased from 40 till 80% and its biomass by 15 times. And at the same time several species of the forage zooplankton – *Cladocera* crawfishes, *Hyponeiston pontelids* (Zaitsev 1992).

Thus, in the present situation, large amount of the production of the lower trophic levels is not exploited, which leads to the decrease of biological productivity of the water reservoirs as a whole. Thus, the so-called «biological contamination» of seas started to develop.

DECREASE OF THE NATURAL REPRODUCTION OF THE ABORIGINAL BIOTA

One of the most important factors of preserving the abundance and diversity of the aboriginal biota species is support of the reproductive function of the populations. The fact that the main components of the fauna have different reproduction cycles makes the marine systems more complicated. For instance, the sturgeon do not spawn every year. They spawn at the age of

10–18 years and the intervals between spawning vary greatly; they are approximately 4–5 years long. Many species of marine mammals do not breed annually. On the other hand, the key fish species in the ecosystem spawn annually (cod, salmon) or 1–2 times during their life cycle (capelin, humpback salmon).

Any breakage of the ecological balance, and high fishing mortality, degradation of the spawning grounds, deficiency of forage in particular, diminish the scale of natural restoration. At the moment, almost all the valuable fish species inhabiting both the northern and the southern seas are subjected to this process. For this reason the majority of commercial fish species have a quicker maturation rate, whereas maximum and average length of fishes in the population became smaller, the rejuvenation of the age composition took place in the populations, their growth rate became quicker.

Pelagic short-lived fish species are the most vulnerable. Natural cycles are typical of their reproduction. If cycles of poor productivity and fishery pressure coincide in time the collapse of the population takes place. Dramatic events of almost complete disappearance of the population of the Barents Sea capelin, Atlantic herring, polar cod might serve as examples of such collapse (Matishov and Pavlova 1990, Matishov 1992, Alekseev and Ponomarenko 1997).

The reason of the catastrophic decreasing of the Barents Sea birds colonies was the deficiency of the forage due to the over- fishing of low-valuable fish species. A typical example of the 8 fold decrease of natural restoration and the abundance of guillemots occurred on the Bear Island (Fig. 66).

The extreme forms of lowering of the natural reproduction of fishes in the second half of the 20th century became typical of the southern seas. After damming of many anadromous and semi-anadromous fishes passages to the majority of spawning grounds already by the end of the 1980s, for instance in the Azov Sea, industrial fish farming began to play the leading role in the increase of the sturgeons, zander and bream populations (Ivanchenko 1997, Rekov 1998, Kovtun et al. 1998). Industrial restoration provided almost 100% of the reserves of white (great) sturgeon, more that 90% of starred sturgeon and 80% of sturgeon. The specialists of the *Azov Fishery scientific-research institute* came to the reasonable conclusion that the irreversible processes take place in the restoration mechanism, which lead to fading away of the natural reproduction of the sturgeons.

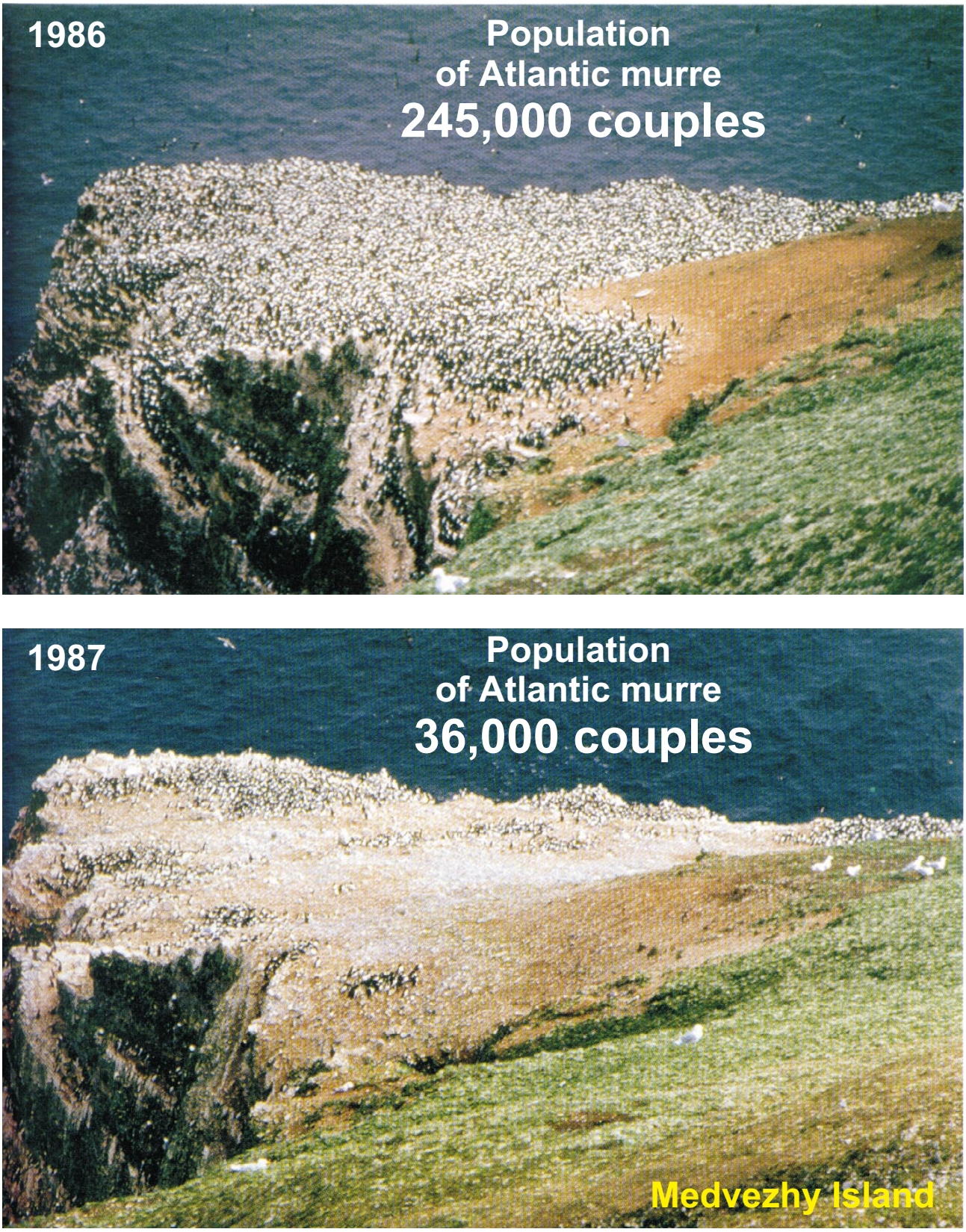


Fig. 66. Consequences of the capelin population collapse impact on the bird colonies (by The State of the European Arctic 1996)